No. 90672 ANTENNA BRIDGE

1. DESCRIPTION

The 90672 Antenna Bridge is an accurate and sensitive bridge for measuring impedance in the range of 5 to 500 ohms for unbalanced input and 20 to 2000 ohms for balanced input (using a 4:1 balun) at radio frequencies up to 200 mc. The variable element in this new bridge is an especially designed differential capacitor of high accuracy and permanency of calibration over a wide range of frequencies. The bridge is entirely different in design from others designed for this type service, in as much as it employs no variable resistors of any sort. The 90672 was designed to use a grid dip meter, such as the Millen 90651 or its industrial counterparts the 90661 or the 90662, as a source of RF signal.

2. APPLICATION

The bridge may be used to measure the antenna radiation resistance, antenna resonance, transmission line standing wave ratio, receiver input impedance, and many other radio frequency impedances. By means of the Antenna Bridge, the transmitter matching unit may be adjusted to provide the minimum standing wave ratio on the transmission line at all frequencies. The RF power from the grid dip meter is coupled to the pick up loop on the bridge and the frequency of the RF power is set to the desired frequency. The knob on the bridge is adjusted for minimum meter reading. The unknown impedance in ohms is read directly from the bridge dial scale. DO NOT UNDER ANY CIRCUMSTANCES LEAVE THE BRIDGE IN THE CIRCUIT WHILE THE TRANSMITTER IS IN USE. The bridge is a measuring instrument not a device for monitoring the performance of transmitters.

The most important part of an amateur radio station, aside from the operator, is the radiating system. The radiating system consists of the actual radiator or the antenna, the device or means for matching the antenna to the transmission line, the transmission line, and the device for matching the transmission line to the transmitter. Rated loading, as indicated by the power input to the transmitter, indicates only that the radiation system is absorbing power from the amplifier. This does not indicate that the power is getting to the actual antenna **unless** an antenna bridge has been used to adjust properly the impedance matching devices at both ends of the transmission line.

The impedance of the antenna varies along its length. A half wave antenna is an electrical half wave length long only at one frequency and has a high impedance at the ends and a low impedance at the center. Since the transmitter and the antenna are separated, an RF transmission line must be used to connect the antenna to the transmitter. Unless the output end of the transmission line is terminated in an impedance equal to the characteristic impedance of the line, power is reflected back along the line from the end. In order to transfer the power from the transmission line to the antenna, it is necessary to match the characteristic impedance of the transmission line to the resistance of the antenna at the point where the line is connected to the antenna. The Antenna Bridge may be used to measure the impedance of the antenna at the point where the transmission line is connected and it may also be used to adjust the matching of the line to the antenna. See section 6 paragraph B for instructions on adjusting the resonant frequency of an antenna, using the Bridge. A balun will be required when the Bridge is used to measure a balanced line.

A transmission line must be terminated in its characteristic impedance at the input as well as it's output end. The impedance of the final amplifier in the transmitter will not be equal to the impedance of the transmission line, so an antenna matching device (sometimes erroneously referred to merely as a loading unit) is required to make the necessary impedance transformation. In many cases the transmission line is matched to the antenna only approximately and the antenna matching unit at the transmitter end of the line is adjusted to get the best over all compensation for securing the minimum standing wave ratio. It is absolutely essential that an antenna bridge be used for proper adjustment of the antenna matching network. The antenna matching unit's purpose is to match the over-all impedance of the antenna and transmission line to the transmitter and in some cases to compensate for the reactance left in the transmission line.

3. OPERATING PRECAUTIONS

CAUTION: Reduce the coupling from the grid dip meter before removing the unknown impedance from the bridge, otherwise the very sensitive null indicator will be damaged. Never use as a power source any pieces of equipment with greater power than a grid dip meter. Never use a transmitter as the power source. See section 5.

4. STANDING WAVE RATIO

Standing waves are caused by energy which is reflected from the terminated end of the transmission line that is not terminated in its characteristic impedance. The reflected energy obviously is not radiated by the transmitting antenna in the case of a transmitter nor is it delivered to the receiver in the case of a receiving antenna. The standing wave ratio is the ratio of the maximum current to the minimum current in a transmission line. When no standing waves are present the maximum and minimum currents are equal and the ratio is one, which means the line is terminated in a pure resistance equal to the characteristic impedance of the line. The standing wave ratio is a measure of the mismatch between the transmission line and its termination.

The power losses in a transmission line are proportional to the square of the current. If the standing wave ratio is too much greater than one the loss increases quite rapidly.

Standing waves on a transmission line to a receiver are caused by reflection at the input terminal of the receiver. The energy is dissipated as described above. In the receiving system it is also necessary to match the receiving antenna to the transmission line for only then will a maximum signal be delivered at the input of the receiver.

The standing wave ratio is the ratio of the load impedance to the line impedance. To measure antenna resistance, couple the Bridge to the antenna by means of a transmission line which is some multiple of a half wave length long at the desired frequency and resonate the antenna at the desired frequency. The method of accomplishing this is described further in section 6. Make the line a half or 1 wave length long to avoid confusion with multiple nulls.

When a "T" match is used the antenna must be re-resonated with each change of the "T". After a proper null is obtained the transmission line length may be changed from ⅛ to ¼ wave length and the impedance as indicated on the bridge should not change. If the impedance indicated on the bridge is changed when the line length is changed, either the antenna is not resonant at the frequency of measurement or the matching is not complete.

5. RF SOURCE

The RF input for the 90672 Antenna Bridge can be any convenient source of power. The Millen 90651 Grid Dip Meter is the recommended source of power. Since a 50 microampere meter is used as a null indicator on the Bridge, do not use too much RF input. The sensitivity of this bridge is very good, consequently loose coupling to a grid dip meter gives all the sensitivity required until the null is reached. At this point tighter coupling to the grid dip meter may be used but at no time is a power source with more output than the grid dip meter required or permissable.

Three RF pick-up loops are supplied with the Antenna Bridge. The large black coupling coil is resonant in the bridge at approximately 5.2 to 8.8 mc. depending upon the impedance setting. At 500 ohms the large coil is resonant at about 5.2 mc., at 50 ohms it is resonant at about 6.2 mc. and at 5 ohms it is resonant at about 8.8 mc. It should be used for all measurements below 12mc. The large white coupling coil is resonant in the bridge at about 15 mc. at 500 ohms, about 19.1 mc. at 50 ohms, and about 30.5 mc. at 5 ohms and should be used for all measurements between about 12 and 40 mc. The smallest coupling loop is resonant at about 32 mc. at 500 ohms, about 39 mc. at 50 ohms, and about 84 mc. at 5 ohms and should be used for all measurements above 40 mc. The largest coupling coil and the intermediate coupling coil result in about the same coupling at about 12 mc. When the bridge is set at 50 ohms the intermediate coupling coil and the smallest coil result in about the same coupling at about 40 mc. Since the greatest coupling occurs with the coupling coil at its highest impedance, the coupling coil which is most nearly resonant at the desired frequency is the coil which should be used. It is, of course, possible to make a coupling coil which will be resonant at the particular frequency at which the measurement is desired. However, experience has indicated that the 8 coils supplied with the Antenna Bridge adequately cover the range and that other coils will be required only under certain very special circumstances.

6. DETAILED APPLICATION INSTRUCTIONS

A. GENERAL USE

1. Couple a voltage of the desired frequency to the Bridge. Since a 50 micro-ampere meter is used as a null indicator in the Bridge, the measurement should begin with loose coupling to prevent the possibility of damage to the instrument.

2. Adjust the coupling by moving either the Bridge or the RF source so that the meter indicates on scale somewhere in the vicinity of 40 micro-amperes, off null.

3. Connect the unknown impedance to the antenna jack. Use the proper coupling plug and in no case use lengthy haywire.

4. Adjust dial for minimum meter reading.

5. Read the value of the unknown impedance in ohms directly from the dial scale.

B. RESONANCE

A point which should not be overlooked in measuring antenna impedance is that antenna resonance must be obtained before the minimum standing wave ratio can be achieved. The antenna is resonant at only one frequency and thus at only this frequency is the impedance a pure resistance. Consequently the antenna must be made resonant at the desired frequency before any attempt is made to match the transmission line to the antenna. Any measurement made off resonance will be misleading.

The Antenna Bridge can be used both to determine resonance and to adjust to minimum standing wave ratio. When the antenna is adjusted for minimum meter reading the impedance at which the standing wave ratio is a minimum has been determined. However, if the meter reading is not zero the antenna is not resonant. By a step by step adjustment of the input frequency, one can find the frequency at which the antenna is resonant. If the antenna is not resonant at the desired frequency it will be impossible to obtain a complete null. The Antenna Bridge can be used easily for obtaining both resonance and minimum standing wave ratio. Furthermore, since the resonant frequency is known, the type of adjustments necessary to bring the antenna to resonance at the desired frequency is known; and since the impedance is known, the adjustments required to minimize the standing wave ratio are known. The bridge indicates when the proper adjustment has been made and also indicates which direction to go to obtain the desired result.

C. UNBALANCED LINES

The Antenna Bridge as it stands can be used directly with unbalanced lines. The shielded portion of the line will be grounded directly to the case of the Antenna Bridge and thus hand capacity and stray capacitances will not affect the measurement. Measurement should be made exactly as outlined above in paragraph A.

D. BALANCED LINES

A balanced line may be measured using the Antenna Bridge by the use of a balun coil, a bazooka transformation for transforming 300 ohm balanced twin line to 75 ohm unbalanced line, or in most cases it will be accomplished by the use of the antenna matching network. When either the bazooka transformation or the balun coils are used, the Bridge is operated exactly as if the line were a quarter of its actual impedance. Both the bazooka and the balun result in a 4:1 impedance ratio. Thus a 300 ohms transmission line properly transformed will read 75 ohms on the bridge, or a 600 ohm open line will read 150 ohms on the bridge. Thus the bridge scale of 5 to 500 ohms becomes 20 to 2000 ohms. This coincides with the usual higher impedances of balanced lines. The use of a balun maintains balance during measurement and thus obviates the wild errors usually encountered when one tries to measure any balanced line impedance without first converting it to a single ended load. The balun coils for the amateur bands are available as additional Bridge accessories.

E. ANTENNA MATCHING UNITS

For proper adjustment of an antenna matching unit; the Bridge is substituted for the transmitter. The coaxial cable from the antenna matching unit, which is usually connected to the transmitter, should be connected to the antenna jack on the Bridge. A grid dip meter or other low power source of radio frequency voltage should be coupled to the Bridge coupling coil. DO NOT UNDER ANY CIRCUMSTANCES LEAVE THE BRIDGE IN THE CIRCUIT WHILE THE TRANSMITTER IS USED. It is desirable after having adjusted the antenna to resonance at the desired frequency as outlined above, to make a table of the dial readings of the antenna matching network which result in minimum standing wave ratio over the frequency range for which it is intended to use the radiating system. When changing frequency it is necessary only to refer to the table of dial readings on the antenna matching network to assure minimum standing wave ratio.

F. QUARTER WAVE LINES

A quarter wave line left open circuit at the output end appears at the input as a short circuit. Lines odd numbers of quarter waves long which are open at the end also appear shorted at the input. With the Antenna Bridge set at the horizontal line at the 5 ohm end of the scale, find the lowest frequency at which an approximate null occurs. This is the frequency at which the line is a quarter wave length long. At approximately three times this frequency another null will be obtained and this is the frequency at which the line is three-quarter wave length long. The quarter wave frequency in mc. is equal to 246 times the velocity of propagation divided by the length of the line in feet. Thus with the length of line known, the frequency at which the line is a quarter wave length long determined by the means of the Bridge, the velocity of propagation can be determined. A quarter wave line may be used to measure the impedance connected at its end. The impedance measured at the input will be equal to the characteristic impedance of the line squared divided by the load impedance. Thus by measuring the input impedance and the characteristic impedance of the line, it is possible to determine the impedance at the far end of the line. In making any of these impedance measurement using twin lead transmission line be certain that the transmission line is set in the open and kept away from ground, etc.

G. HALF WAVE LINES

A half wave length line short circuited at the output end will appear short circuited at the input end. In other words a half wave line will repeat its termination impedance. Set the Antenna Bridge dial to the horizontal line at the 5 ohm end of the dial scale and find the lowest frequency at which an approximate null is obtained. This is the frequency at which the line is a half wave length long. Any multiple of a half wave length will also produce a null. Half wave lines will repeat at the input end the impedance connected to the output end. Thus a half wave line may be us to determine the impedance in which it is terminated merely by measuring the input impedance.

H. CHARACTERISTIC IMPEDANCE

The characteristic impedance or the surge impedance of a transmission line may be measured by leaving the output end open circuited. Set the Antenna Bridge to the horizontal line at the 5 ohm end of the dial scale, find the lowest frequency at which the transmission line is a quarter wave length long. Now terminate the ends of the transmission line in a resistor. For 50 ohm line use about 80 or 100 ohms. For 100 ohm line use 50 or 200 ohms. For 800 ohm line use about 200 or 600 ohms. Find the new Bridge null, still leaving the rf source frequency at the quarter wave frequency. The characteristic impedance of the line will equal the square root of the Bridge reading, sometimes called the "inverted impedance," times the square root of the load resistance. It may be necessary to measure the load resistance at the frequency in use. It is possible that the "inverted impedance" is not within the 5 to 500 ohm range of the Antenna Bridge. If this should be the case, try a somewhat different terminating resistance until the "inverted impedance" is within the range of the Antenna Bridge.

I. ANTENNA RESONANCE AND RESISTANCE

Since a grid dip meter is generally available as a power source for the Antenna Bridge, antenna resonance is often determined easiest by means of the grid dip meter. However, in many cases where the antenna Q is low, or when the element diameter is large, it is difficult to use the grid dip meter to find antenna resonance and in many cases it is physically impossible to reach the proper point in the antenna without changing the physical position of the antenna. It is often hard to couple to a long wire at low frequencies, thus in many cases it is convenient to determine the antenna resonant frequency by means of the Antenna Bridge. Paragraphs J through O discuss measurements on particular types of antennas.

J. HALF WAVE DIPOLES

The easiest way of determining the resonance of a dipole antenna is to use a half wave transmission line between the antenna and the Antenna Bridge. The transmission line should be a half wave length long at the resonant frequency of the antenna. This is not as ambiguous as it sounds on the surface, because the frequency of the antenna is known approximately because the physical length in the standard formula will give the approximate frequency. The transmission line should be cut to a half wave at this calculated frequency. Cut the line slightly long so that successive approximations may be made so that a precise measurement may be made.

It is often desirable to cut an antenna to a particular resonant frequency rather than to measure the resonant frequency of an existing antenna. In this case, the transmission line should be made a half wave length long at the desired frequency and the antenna pruned to resonance. One precaution should be observed: The half wave length line must be at right angles to the antenna for at least a quar-

ter wave length in order to eliminate any coupling between the antenna and the transmission line. Failure to observe this precaution will result in erroneous answers. At high frequencies, it may be desirable to use a transmission line which is some multiple of a half wave length long. The impedance of the transmission line is not important, since it is being used only as an impedance "repeater" rather than to match the antenna.

If a balun is available, and if the frequency of measurement is lower than about 50 mc., the bridge may be used directly at the center of the antenna. Since the center impedance of a dipole is about 72 ohms, set at the Bridge dial to about 72/4 equals 18 ohms and adjust the source frequency and Bridge dial for null. Here again, do not be too alarmed if the measurement does not coincide with previous impressions. The impedance should be dependent on the height of the antenna above ground. It can be determined whether the positions of the Antenna Bridge and the operator near the center of the antenna result in erroneous readings, by noticing whether or not the meter null changes when the operator moves away from the antenna. If position errors exist it will be necessary to resort to a half wave transmission line to measure as outlined in paragraph J above. At frequencies above 50 mc., the presence of the bridge and the operator at the center of the antenna will probably result in errors which will not occur when the bridge and the operator are removed from the center of the antenna. If a balanced transmission line, such as open line or twin line is used between the antenna and the Bridge, line unbalance to ground may be reduced by twisting the line every couple of feet or so. If a different reading is obtained when the line connection to the balun is reversed, unbalanced line to the ground capacity is indicated and should be corrected by twisting the transmission line.

K. FOLDED DIPOLES

The Bridge balun or the half wave line should be connected to the center of one side of the folded dipole (the point at which the transmission line is usually connected). The radiation resistance of the folded dipole is usually between 150 and 800 ohms or so. If the folded dipole is made of twin line it has a velocity of propagation such that the quarter period of the quarter wave length line is about 86% of the over all natural quarter period. Two impedances will be indicated on the Bridge. The correct indication is the one between 150 and 300 ohms, and the incorrect indication will be around 500 ohms. Consequently, the correct Bridge reading is the one that occurs at the highest frequency. This type of antenna results in narrow band pass. It is possible to use the Antenna Bridge to compensate for the velocity of propagation and thus broaden the frequency response of a twin lead dipole to equal the band pass of an open wire dipole. One method of compensation is to place in series with the shorted ends a capacity of about 7 mmf per meter of wave length and tune each quarter wave section to the over all natural frequency. Another is to place short circuits at 86% of the normal distance from the center to each end. Another method is to cut the line of the folded dipole so that it is 492 times the velocity of propagation divided by the frequency in mc. feet long. A transmission line of twin lead should be cut to a half wave length at the desired frequency as outlined above in paragraph G. Short circuits should be placed at ends of the antenna. Open one side of the antenna and connect the Bridge balun or the half wave transmission line "repeater". Add a wire to each end of the folded dipole. Clip the wires back until antenna resonance is indicated at the desired frequency. The frequency response of an antenna made in this manner will approximate that of an open wire folded dipole.

L. HARMONIC ANTENNAS

To measure antennas any multiple of a half wave length long, connect the balun or the half wave transmission line "repeater" at any high current point.

M. QUARTER WAVE VERTICLE AND GROUND PLANE ANTENNAS

The impedance measured at the bottom of a quarter wave antenna is of the order of 35 ohms. The Bridge should be connected between the bottom of the antenna and the ground plane. If the transmission line impedance is higher than the end impedance of the vertical antenna, which is the usual case, the feed point impedance may be increased by increasing the angle between the radiator and the ground plane radials. Use the Antenna Bridge to determine the proper angle of the ground plane radials. The limit that can be achieved is about 70 ohms at which point the angle between the antenna and the ground plane radials is 180° and the antenna is a coaxial antenna.

N. MOBILE ANTENNAS

The bottom impedance of a quarter wave radiator placed on a car will be about 45 ohms. This impedance can be measured exactly as described in paragraph M above. For base loaded or center loaded antennas, the impedance will be 20 to 85 ohms. In order to measure, the base loading should be connected between the base of the antenna and the Antenna Bridge,

and the Antenna Bridge should be connected between the base loading and the ground plane of the car. Use the Antenna Bridge to determine what L and C are required for base loading, in order to match the antenna to 50 to 70 ohm transmission line.

O. PARASITIC BEAMS

The bridge should be connected by means of a balun or a half wave transmission line "repeater" to the center of the driven element. The impedance at this point will probably lie between 5 and 100 ohms. More than one null will be obtained due to the reflections from other elements, however, a properly tuned beam will have only one **complete** null at the true resonant frequency. Adjust the length of the driven element to resonance as described in paragraph I. The reflectors should then be cut to 5% longer than the driven element and directors should be cut about 5% shorter than the driven element. It is, of course, possible to tune the reflectors and directors but the improvement in the performance is seldom worth the additional effort.

P. ADJUSTING Q BARS

Q bars are used as a quarter wave trans-

former to match the antenna resistance to the line characteristic impedance. Connect the end of the bars to the Bridge balun or half wave transmission line "repeater" and the other end to the antenna. Adjust the spacing for the desired impedance. However, before the Q bars can be adjusted, the antenna must be resonant as determined in paragraph I and the Q bars must be a quarter wave length long.

Q. RECEIVER INPUT IMPEDANCE

If the receiver input is unbalanced, connect the bridge directly to the receiver input. If the receiver input is balanced, connect the receiver input to the Bridge balun. The input circuit of the receiver must be resonant in order to measure the input resistance. Over coupling between the antenna coupling coil and the first tuned circuit is a common condition and will be indicated by two bridge measurements, one of which will be in the vicinity of 5 to 20 ohms and the other 50 to 1500 ohms. Too loose coupling between the antenna coupling coil and the first tuned circuit is indicated by an incomplete null which results because the input is reactive.

The receiver input impedance may be matched by a network such as the Millen No. 92101 Antenna Matching Preamplifier.

7. TECHNICAL SUMMARY

POWER INPUT

No D.C. or 60 cycle power required.

A small fraction of a watt of rf power is required. It is suggested that a Millen 90651 Grid Dip Meter be used to supply this power.

IMPEDANCE RANGE

Unbalanced—5 ohms to 500 ohms

Balanced—20 ohms to 2000 ohms using balun not supplied with Bridge.

ACCESSORIES (Not included)

Millen 90651 Grid Dip Meter.

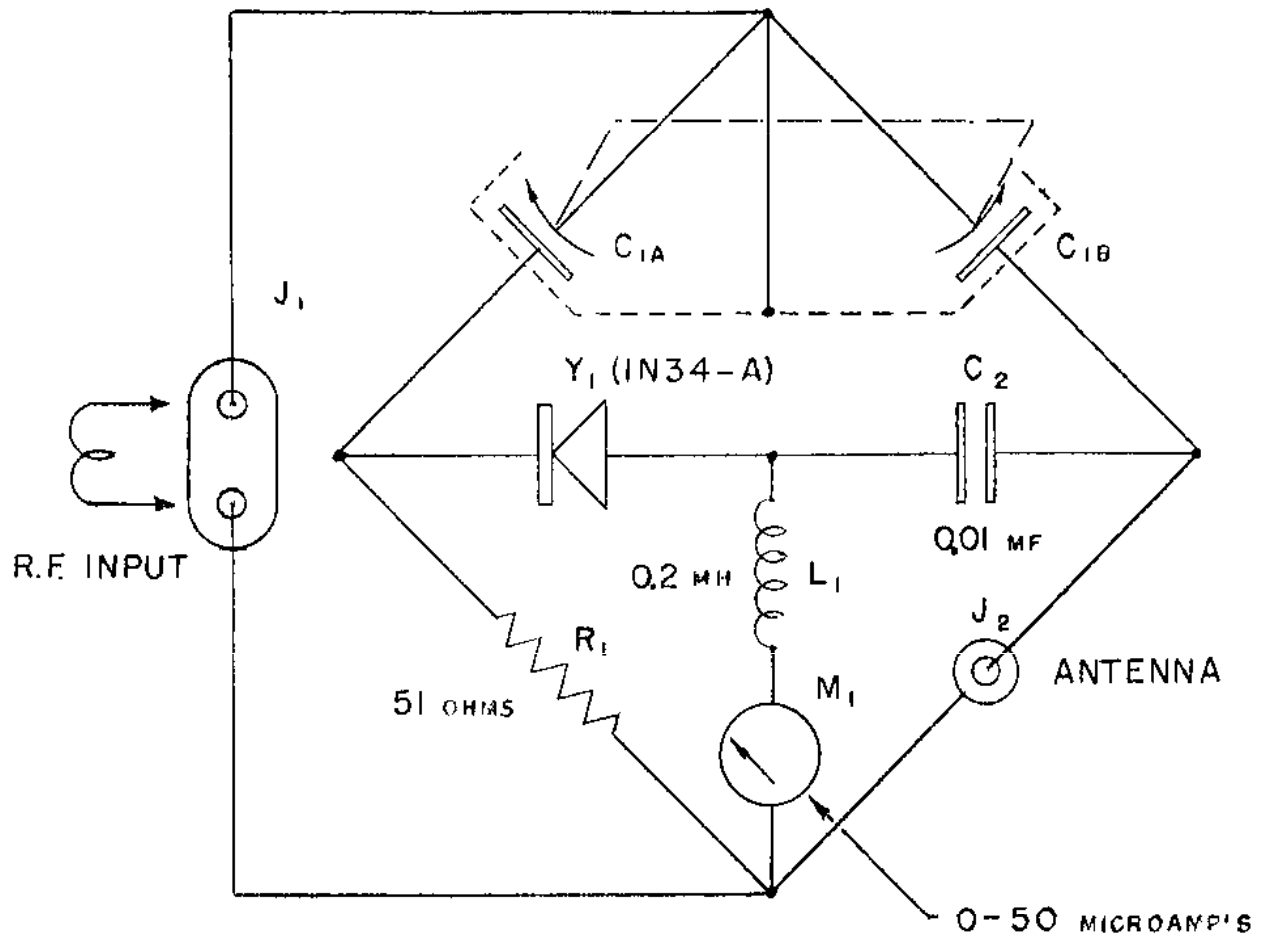Baluns for the amateur bands.

PHYSICAL DIMENSIONS

Length—5⅝ inches.

Width—8⅛ inches, plus rf connector.

Height—3⅞ inches, including knob.

Weight—1⅝ pounds.

R.W.C. 9/2/55

R.F. INPUT

J_1

C_{1A}

C_{1B}

Y_1 (1N34-A)

C_2

0.2 MH L_1

QOI MF

R_1

51 OHMS

M_1

J_2 ANTENNA

0-50 MICROAMP'S

ALL DIMENSIONS UNLESS OTHERWISE NOTED MUST BE HELD TO A TOLERANCE OF

ANTENNA BRIDGE

FIRST MADE FOR

DESIGNED BY R.W.C.   CHECKED BY R.W.C.

DRAWN BY R.KAROSAS   APPROVED

JAMES MILLEN MFG. CO., INC.
MALDEN, MASS., U.S.A.   K 90672

DATE 8-23-55

INSTRUCTIONS

for

ANTENNA BRIDGE

Cat. No. 90672 - Serial No.

JAMES MILLEN MFG. CO., INC.
MALDEN, MASS., U. S. A.